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THE MARKET VALUE OF LISTED HERITAGE: AN URBAN ECONOMIC APPLICATION OF SPATIAL HEDONIC PRICING

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Abstract

The current literature often values intangibles goods as cultural heritage by applying stated preference methods. In recent years, however, the increasing availability of large (spatial) databases on real estate transactions and listed prices has opened up new research possibilities and has reduced various existing barriers to applications of conventional (spatial) hedonic analysis to the real estate market. This now offers a promising new avenue for further research on the economic value of cultural heritage in the context of the urban housing market.

The present paper provides one of the first spatial hedonic studies that investigates the economic effects of listed heritage –in particular, urban monuments and historic-cultural sites– on the value of real estate in cities. In addition, this paper aims to contribute to the spatial-econometric valuation literature by providing a novel quantitative analysis of an extensive micro data set on individual housing transactions over 22 years in the Dutch city of Zaanstad.

In this paper the monument status effect is analysed in two interrelated ways. First, we measure the direct effect of monument status on the market price of the houses in the relevant area concerned. Secondly, we investigate the indirect value that monuments have on nearby property.

Using spatial econometric techniques, we find that, controlling for other attributes, buyers are willing to pay an additional 26.9 per cent to purchase a monument, while surrounding houses are worth an extra 0.28 per cent for each additional monument within a 50-metre radius. Houses sold within a historic protected area appear to gain a premium of 26.4 per cent which confirms the existence of a historic ensemble effect.

Keywords: Cultural heritage, monument status, valuation methods, stated preference methods, hedonic prices, spatial statistics, spatial autocorrelation, historic buildings

JEL codes: C210; R200

Pn398flprjr

1. Introduction

It is generally recognized that the identity of a city is closely related to the remains of its past. Historic buildings are often an important aspect of the ambience of inner city neighbourhoods, and sometimes even characteristic for the city as a whole, as is witnessed e.g. Rome, Jerusalem, Cairo, Marrakech or Amsterdam. This built heritage is part of the cultural capital of cities, and the importance of this asset has recently been stressed by many authors (see e.g. Fusco Girard and Nijkamp 2009; Throsby 2001). More generally, urban economists have stressed the importance of urban amenities for the attractiveness of inner cities as a place of residence (see e.g. Brueckner et al. 1999; Glaeser et al. 2001). A historic centre is probably the most important example of such an amenity.

The general awareness of the importance of historic buildings for the urban economy raises the question how the social value of such buildings can be determined. One may try to find part of the answer by studying the value of monuments[1]. The characteristic buildings of ancient inner cities often have the status of a monument. This status may be used as an indicator of cultural heritage (for a discussion of the designation process, see Noonan and Krupka 2010). Researchers who have tried to assess the value of monuments have often relied on stated preference methods (for a survey, Snowball 2008; Noonan 2003), but there is also a smaller literature that uses hedonic analysis, but to our knowledge there have been no hedonic analyses based on spatial-econometric techniques. The hedonic price technique offers the possibility to investigate two aspects of the valuation question: it allows a researcher to compare the value of a monument with that of otherwise comparable real estate, and it enables him to study the effect of a monument on the value of neighbouring properties. Quantitative information about these two aspects is potentially useful for city planners who have to decide about conflicting claims on urban space arising from – for instance – the necessity to extend transport infrastructure and the desire to preserve the characteristic ambience of an ancient inner city.

Our analysis refers to the Dutch city of Zaanstad, a municipality which is linked to the history of the Golden Age of the Netherlands in the 17th century. To investigate the impact of monuments on the value of its housing stock, we conduct a hedonic regression. We estimate the effect of monument status on the value of a property designated as such – and will refer to this as the 'direct effect' – as well as its external effect on neighbouring properties – referred to as the

[1] In this paper, the term 'monument' is used in the Dutch sense, whereby 'monuments' include all types of historic buildings, including houses. In British English, the term 'monument' refers only to public heritage such as Nelson's Column in Trafalgar Square, London, the prehistoric site of Stonehenge, etc. Otherwise, historic buildings used for a particular purpose are called 'Listed Buildings' (Grades I, II and III), which includes houses of architectural merit. In American English the equivalent of monument is 'landmark' for all types of historic buildings.

‘indirect effect’. Both effects are part of the social value associated with monuments, and of the cultural heritage they represent.

Previous hedonic studies have often been limited by a modest number of observations. This paper now attempts to contribute to this literature by providing an analysis of an extensive data set on prices related to actual housing transactions over a long period, some of them referring to monuments, which is enriched with complete information about the presence of monuments in the city that we are studying (viz. Zaaanstad). In correcting for spatial dependence, this is, to our knowledge, the first spatial hedonic analysis which focuses on the direct and indirect effects of monument status. As far as we know, the idea of a time-sensitive decaying modelling approach to calculating the spatial weight matrix is new.

The remainder of the paper is organised as follows. In Section 2 the literature on hedonic price methods and their application to cultural heritage is reviewed, while a short discussion of spatial dependence is given. After examining the literature, in Section 3 the study region and the data are discussed. Then, Section 4 presents a hedonic price model for assessing the impact of listed heritage on house prices, while its spatial dependence is analysed. After presenting the outcomes of the hedonic price model, in Section 5 various spatial extensions are made and discussed. Finally, Section 6 concludes and discusses some potential fruitful avenues for further research.

2. Literature review

Hedonic price studies have already a long history in economic research. They are based on revealed market behaviour in case of non-market values of the attributes of the good concerned. Thus, a hedonic price model is essentially a quality-adjusted market price model, especially in case of externalities. Although the first applications date back almost a century ago, it became a central tool in economic analysis with the seminal article of Rosen (1974).

The hedonic price method is based on the observation – often attributed to Gorman (1956) or Lancaster (1966, 1979) – that *“…goods are valued for their utility bearing attributes characteristics”*. If we consider a dwelling to comprise a bundle of attributes, then the implicit prices of these different attributes can be measured. Like ordinary prices, these implicit prices reveal the marginal willingness-to-pay (WTP) of consumers (Baranzini et al. 2008). Many hedonic price analyses address the value of real estate, often house prices. There is indeed a wealth of literature on hedonic valuation of the housing market; surveys can be found amongst others in Ekeland et al. (2002), Palmquist and Smith (2002), Sheppard (1999) and Taylor (2003). The WTP for monuments or the proximity to monuments is the central focus of this paper.

Some early studies concentrate on the effect of the designation of a building or an area as cultural heritage (for a survey, see Leichenko et al. 2001). One of the first studies using a full hedonic price function is Ford (1989). Using data on sold houses provided by multiple listing services in several neighbourhoods, Ford finds that historic districts in Baltimore gain price premiums over similar properties elsewhere in the city after having been designated as such. In the same vein, Schaeffer and Millerick (1991) show that designation as cultural heritage by local or national authorities has different effects: designation by the national authority was found to have a positive influence, whereas designation by a local authority had a negative impact. More recently, Deodhar (2004) finds a 12 per cent premium for houses being designated as cultural heritage, controlling for other property attributes in Ku-ring-gai, a historic district along Sydney's upper north shore. A study conducted by Noonan (2007) shows that designated landmarks sell for a 10.6 per cent premium over comparable properties, while properties located in landmark districts receive only a 3 to 5 per cent premium.

Asabere et al. (1994) make a distinction between local and national historical-designated apartments, and find that local historical-designated small apartments experience a 24 per cent reduction compared with non-designated apartments. Unlike this significant local historical-designated result, the national historical-designation variable included in their model produces insignificant results. The study of Asabere and Huffman (1994) finds a positive impact of federally-certified historic districts. Residential property located in a federally certified historic district sells at a 26 per cent premium compared with a similar property outside the district. Some more recent studies use individually designated property instead of districts. Narwold et al. (2008) show that designation creates a 16 per cent increase in house value which is higher than the capitalization of the property tax savings related to designation, which suggests additional economic value of cultural heritage.

The studies above discussed concentrate on the direct effect – the marginal impact of the designation or cultural heritage on the property itself. But there is also a small literature that focuses on the external effect – the spillover effects on neighbours – of historical real estate. Schaeffer and Millerick (1991) state that neighbourhood externalities are thought to be substantial. Noonan (2007) finds, using a repeat-sales methodology, that the external effects of designation are stronger when more cultural heritage gets designated in an area. Coulson and Leichenko (2001) use the percentage of houses in the census tract that are designated in order to measure the externality effect, and find positive and significant neighbourhood effects of designated houses. Each additional designated house within the census tract increases the value of each house in that census tract by 0.14 per cent.

Most hedonic price studies refer to the US. Our empirical work refers to the Netherlands. As far as we know, Ruijgrok (2006) is, to date, the only researcher who has used a hedonic pricing method to value cultural heritage in the Netherlands. She focused on cultural heritage in the old Hanseatic town of Tiel. In her study, houses with a national or municipal monument status were compared with otherwise comparable houses. She finds a positive effect of almost 15 per cent (Ruijgrok 2006).

An important concern when using the designation of a property as an explanatory variable is that it can have several effects. The interest in this paper is in its role as an identifier of cultural heritage. But monument status also implies restrictions on the use that can be made of the property, since changes in its outward appearance are often prohibited (Coulson and Leichenko 2001). This can have a negative effect on the value of the property. On the other hand, receiving monument status may also imply that subsidies or tax exemptions can be claimed, and this probably has a positive effect.

Many of the studies mentioned struggle with the problem of a limited number of observations and limited information about housing and neighbourhood characteristics. This may be one of the reasons why stated preference studies have been more popular than hedonic price studies (see, for instance, Navrud and Ready 2002, and the references therein). These data problems can be overcome by the use of large databases that have become increasingly available. For instance, in this study we use transaction data that cover the majority of houses sold in the Zaanstad municipality over the years 1985-2007, and combine it with information from the Land Registry about the stock of national monuments in this area and GIS data about neighbourhood characteristics. With such data, the problem of omitted variables can be mitigated considerably, while the large number of observations enables the analyst to incorporate a satisfactory number of regressors. The hedonic price model regresses prices on transaction-related, structural and spatial characteristics. Spatial dependence in the form of spatial autocorrelation or spatial heterogeneity may well have an impact on prices (Anselin 1988). In the following section the study region is discussed followed by a discussion of our unique micro data.

3. The study region and data

As stated in the preceding section, the direct and indirect effects which monument status has on the housing in an area are often not studied in detail because of the lack of detailed micro-data. This study offers the opportunity to study these effects in depth because of the availability of very detailed micro-data. This section first describes the study region and provides a next comprehensive discussion of the data which was used to estimate the (spatial-econometric) hedonic model.

Study region

In discussing the study region we focus on in which way monuments are related to the urban region Zaanstad and some specific housing market conditions. The most important city of the municipality of Zaanstad is Zaandam, which is situated on both banks of the Zaan River (for an overview of the municipality see Figure 1). Apart from the city of Zaandam, the Zaanstad municipality contains a number of smaller villages. During different periods in history, the Zaan district played an important role in the industrialization of the Netherlands; the district is even believed to be the world's first industrialized area. Throughout the Dutch Golden Age in the 17th century, the Zaan district was dotted with windmills, which processed materials such as linseed, used in the paint industry, and agricultural products such as mustard seed and wood. By the mid-17th century, there were more than a thousand windmills on both banks of the Zaan River (De Vries and van der Woude 1997). The shipbuilding industry in the Zaan area was so advanced that Czar Peter the Great from Russia studied shipbuilding in the Zaan district in 1697 during his "Grand Embassy" through Western Europe. The "Czar Peter house" is a physical remainder of his stay, and is one of the important monuments of Zaandam. Later in history the Zaan area played an important role in the industrialization of the Netherlands. A number of major Dutch companies, like Ahold and Verkade, were founded here.

This rich history of the Zaan area resulted in a wealth of cultural built heritage. Zaanstad has 281 national monuments, 64 provincial monuments, and 150 municipality-based monuments. In addition, three small neighbourhoods have been designated as protected areas because of their characteristic old buildings (see Figure 2). The Dutch Land Registry Office (Kadaster) and Dutch Heritage provided complete information about the location of national and provincial monuments in the municipality. In the Netherlands the listing process is rather complex and lengthy, and it is conducted by the experts of Dutch Heritage, a national expert centre. In their listing procedure the office tries to objectify why the monuments are cultural heritage and of significance. After being listed, the monument status is rather static.

According to the Monument Law of 1988, a national monument is a property (building, object, city or village view) which is of public interest for its beauty, the meaning for science, or its cultural historic value. The minimum age is 50 years. Among the types of monuments distinguished are: architectural heritage, religious heritage, industrial heritage, and UNESCO world heritage. The fortresses which are part of the "Defence Line of Amsterdam", the Dutch defence line around Amsterdam belongs to the latter category.

Data

The transactions data used have been provided by the Dutch Association of Real Estate Agents (NVM) [2] and concern housing transactions from 1985 to 2007. Figure 3 shows the number of sold houses per village in the municipality of Zaanstad where the number of sold monuments is presented between parentheses. As expected, because of their special status only a small proportion of the sold houses in our database refer to monuments. Over the 22 years

[2] In the Netherlands 65-70 per cent of all houses are sold by an NVM-real estate agent.

covered by our data, 51 transactions refer to monuments, which means that even over this long period only a proportion of the total number of monuments was ever sold. However, in order to properly interpret this figure, one should realize that mobility on the Dutch housing market is relatively low: the total number of owner-occupied houses in the Zaanstad municipality is 30,000 – which covers 50 per cent of the housing stock – and the total number of transactions of the 22-year period we study was 20,000. The transactions show considerable spatial spread.

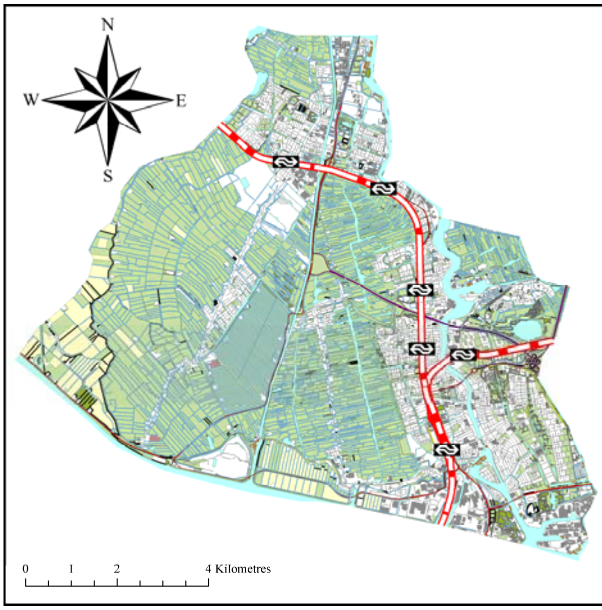

Fig. 1 Overview of the municipality of Zaanstad

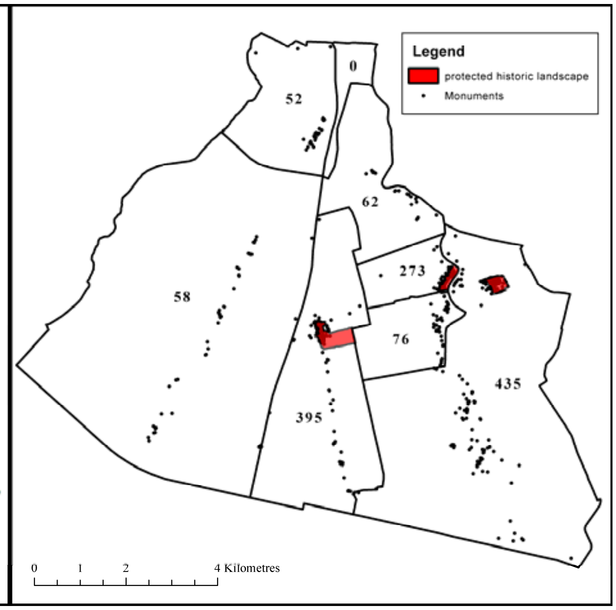

Fig. 2 Monuments and protected historic landscape

Without controlling for other attributes, it appears from Figure 4 that, on average, the towns of Wormerveer, Koog aan de Zaan and Zaandam have moderate transaction prices, while Westknollendam and Westzaan are expensive.

The NVM-real estate agents provide numerous transactional, structural and spatial characteristics of each sold house. The data is enriched with information obtained from Statistics Netherlands about neighbourhood characteristics: population density, percentage of non-Western migrants, and percentage of water in the total area in a neighbourhood. The complete monument characteristics are obtained from the Land Registry Office and Dutch Heritage.

The names and definitions of all variables that have been included, as well as the descriptive statistics, are presented in Tables 1 and 2 of the Appendix. The registered selling price is the actual price paid for the dwelling. We are also able to control for other *transaction characteristics*. One characteristic that may be typical for the Netherlands is that the land on which the house is built can be leasehold. In that case, the owner rents the land on which his house is built and only owns the house. Other important transaction-related characteristics are, of course, the year in which the transaction took place and the selling conditions.

The structural characteristics include floor area, capacity, number of rooms, different types of gas heater, types of insulation, quality of maintenance of the inside and outside of the house, garden characteristics, and parking opportunities. In addition, the state of maintenance of the house, as reported by the realtor, could also be included. *Spatial characteristics* include distance to the centre of Zaandam, whether the house is situated on a busy street, population density, and the percentage of non-Western immigrants. Further a dummy for the various villages within Zaanstad is included.

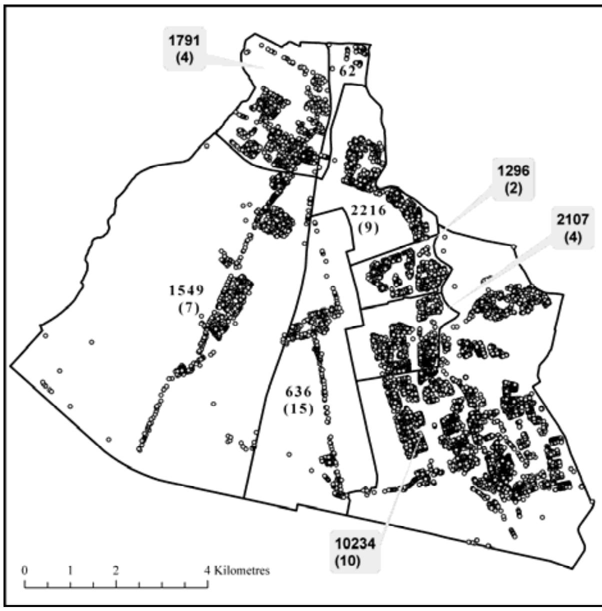

Fig. 3 Sold houses, number of sold monuments between parentheses

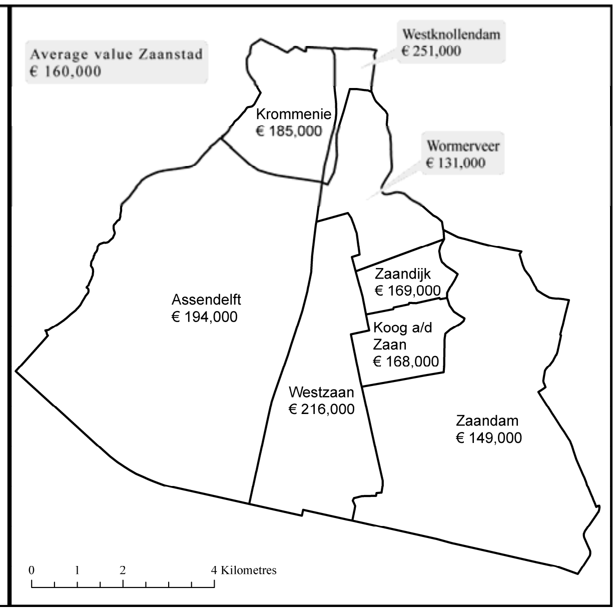

Fig. 4 Value per village in Zaanstad 2000 prices

This paper investigates the economic value of monument status. For this we need information about the monument status of buildings located near sold houses and that, of the sold houses themselves. As previously stated, the NVM-real estate agents also register the monument status of the sold property which offers the opportunity to estimate its direct effect on the property. The hypothesis is that a monument generates extra utility to its owner and thus a higher WTP. Besides tax abatements or reduction, the connection of the owner to the history of the house may generate this premium compared with other houses. The indirect effect – the external effect – of houses with monument status on their neighbourhood is measured by another monument characteristic: the number of monuments in the vicinity of the property being sold.

Thanks to the Dutch Land Registry Office and Dutch Heritage we have complete information of all the monuments in the municipality. It seems likely that this external effect is spatially limited to, at most, a few hundred metres. One may be willing to pay more for a house located next to a splendid old building than for an otherwise similar house located in a neighbourhood of uniform quality housing, but the presence of such a monument at a distance of, say, 500 metres will probably hardly affect ones' WTP. To take this into account we measure at various distances the number of monuments and calculate the monument density. Finally, we are able to determine whether a sold house is situated within a protected historic landscape (see Figure 2). These protected historic areas are ensembles of characteristic old buildings. One of the hypotheses is that buyers gain extra utility from the historic decor over the utility that a single monument has.

Before presenting the estimation results, it should be noted that our hedonic analysis only refers to the owner-occupied sector of the housing market. The large majority of the rental part of the housing stock is social housing which is rent-controlled. Maximum rents are determined on the basis of a set of quality characteristics which ignore location or monument status. For this reason, a hedonic analysis of the market for rental housing is not meaningful for the Netherlands, and we have to restrict the analysis to the owner-occupied part.

4. Hedonic price model based on OLS

In this section the results of the hedonic price model are discussed, whereby we focus in more detail on the effects which monuments – the direct and the indirect effect – have on their own price and the neighbouring house prices. It is assumed that monument status has a positive effect on price of both the house itself and the neighbouring houses.

The hedonic price function is a conventional log-linear specification and, as described earlier, it uses a rich set of control variables to reduce omitted variable bias as far as possible (see Table A.1 of the Appendix for a complete list of variables). The results of the OLS regression are presented in Table 1. The dependent variable is the natural log of the transaction prices. As expected, more recently sold houses are more expensive than houses sold earlier, which is indicated by the significant year of the transaction dummies. The various OLS models explain more than 79 per cent of the variance in the dependent variable.

Houses of which land is leasehold sell at a discount of 4.7 per cent. When house owners own their land they are prepared to pay this amount as a premium to reduce uncertainty. Structural characteristics such as the number of rooms, floor area, and capacity, all have a positive and significant effect. A terraced house, a maisonette, a porch and gallery flat, obtain a discount compared with a single family house, whereas a mansion, farm, bungalow, villa and country house gain a premium. House type is included in the regression but is omitted from the table to keep the table compact. Different building types of houses are closely related to their building period, e.g. canal houses were mainly built during the 'Golden Age'. Luckily, the classification of house type used by the Dutch Association of Real Estate Brokers (NVM) is hard to link with their related building period which reduces the risk of multicollinearity.

Also the spatial characteristics are significant, and the reported coefficients have the expected sign and magnitude. As stated earlier, the history of the municipality of Zaanstad is closely related to the presence of water. We see that an increase of 1 per cent of the water surface in a neighbourhood adds 0.17 per cent to the value of houses in that neighbourhood. An additional 1 per cent of non-Western immigrants in a neighbourhood decreases house prices by 0.16 per cent.

The external effect of monument status which uses the monument density within 50 metres of a sold house is measured by means of the presence of the number of monuments. Their relative availability indicates what proportion of the site is occupied by monuments. One can imagine this in two ways. In the first place, one monument in a highly built-up neighbourhood has only a marginal effect on that neighbourhood because the general ambience is general non-monumental, whereas neighbourhoods with a high density of monuments gain a premium. Secondly, there could be a decreasing marginal WTP for monuments, if their presence is relatively abundant, because of satiation.

After controlling for transaction-related, structural and spatial characteristics, monuments are found to make a positive and significant contribution to house value of approximately 21 per cent, over non-monuments. This direct effect means that potential buyers, according to the baseline estimates, are willing to pay an additional €33,600 in the year 2000 prices to purchase an average priced monument.

The indirect effect which is measured by the monument density within a 50-metre radius[3] is significant in the first model. One additional monument increases house prices within a 50-metre radius by 0.24 per cent in the baseline model. In the second model, the presence of a historic neighbourhood is investigated by including protected historic landscapes in the regression[4]. One of the consequences is that the external effect is cancelled out completely when this historic ensemble effect is included. Houses which are within this historic ensemble gain a large premium of 23.4 per cent over houses which are not benefiting from this ensemble effect which is a premium of €37,400 based on 2000 prices for an average dwelling. These results imply that a monument that happens to be located in a protected historic landscape has a value that is about 47 per cent higher than a similar dwelling without these two heritage dimensions.

An interesting result of a sensitivity analysis is that the monument density times the trend – which checks for the externalities of those monuments on their neighbours over time – is positive

[3] Different radius specifications were tested but it seems plausible to choose relatively steep distance decay.

[4] The correlation between the monument density and the protected historic landscape is large with a value of 0.69.

and significant. This means that, over time, people value the monuments in their neighbourhood more highly.

Table 1 Ln(price) regressed on explanatory variables

Variables	Direct and indirect monument model			Monument ensemble model		
Transaction-related characteristics						
Leasehold	-0.0486	***	(0.0053)	-0.0482	***	(0.0053)
Newly-built house	0.0180		(0.0173)	0.0193		(0.0173)
Sell condition (seller)	0.0106		(0.0190)	0.0122		(0.0190)
Sell condition (auctioned)	-0.2092	***	(0.0266)	-0.2252	***	(0.0266)
Structural characteristics						
Ln(Floor area)	0.1801	***	(0.0180)	0.1799	***	(0.0179)
Ln(Capacity)	0.4822	***	(0.0183)	0.4805	***	(0.0183)
Ln(Rooms)	0.0212	***	(0.0067)	0.0213	***	(0.0067)
Construction period unknown	-0.0995	***	(0.0246)	-0.1063	***	(0.0246)
Built before 1906	-0.1599	***	(0.0115)	-0.1619	***	(0.0115)
Built in the period 1906-1930	-0.1757	***	(0.0101)	-0.1762	***	(0.0101)
Built in the period 1931-1944	-0.1112	***	(0.0102)	-0.1121	***	(0.0102)
Built in the period 1945-1959	-0.0848	***	(0.0125)	-0.0859	***	(0.0124)
Built in the period 1960-1970	-0.1030	***	(0.0100)	-0.1035	***	(0.0100)
Built in the period 1971-1980	-0.0596	***	(0.0099)	-0.0589	***	(0.0099)
Built in the period 1981-1990	-0.0107		(0.0100)	-0.0122		(0.0100)
Built in the period 1991-2000	-0.0017		(0.0097)	-0.0022		(0.0097)
Spatial characteristics						
Busy street	-0.0072		(0.0060)	-0.0070		(0.0060)
Proportion of water areas	0.1537	***	(0.0236)	0.1549	***	(0.0235)
Population density	-0.0072	***	(0.0008)	-0.0071	***	(0.0008)
Percentage ethnic	-0.0016	***	(0.0002)	-0.0016	***	(0.0002)
Distance to centre in km	0.0008		(0.0022)	-0.0004		(0.0022)
Monument amenities						
Monument density/ha at a 50-metre radius	0.0024	***	(0.0005)	-0.0011	**	(0.0006)
Monument dummy	0.1904	***	(0.0251)	0.1779	***	(0.0251)
Protected historic landscape				0.2104	***	(0.0260)
Constant	8.4624	***	(0.0463)	8.4743	***	(0.0463)
Observations	19981			19981		
Adjusted R-squared	0.9277			0.9279		

Notes: Standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.10.
Only part of the estimated coefficients is reported, full estimation results are available from the authors upon request.

5. Spatial hedonic price model

As Tobler's (1979) *first law of geography* indicates: "everything is related to everything else, but near things are more related than distant things", house prices are determined by their location. Anselin (1988) defines spatial dependence as: "the existence of a functional relationship between what happens at one point in space and what happens elsewhere" (for an overview of spatial econometrics, see Anselin 1988, 2006, 2010; Elhorst 2010).

The location where cultural heritage is situated is most likely not the outcome of some random process; it is more likely that the spatial fundamentals play an important role in the development of the built cultural heritage. In the first place, historical spatial fundamentals play a role in the choice whether to build in a certain location or not. When those historical spatial fundamentals are currently not observed, and thus are not incorporated in the hedonic model, this may lead to spatial bias. Secondly, when the choice of which heritage is listed on a monument list and is worth preserving is correlated with unobserved spatial attributes, this may lead to spatial autocorrelation in the specified model. To test for the presence of spatial dependence we use a classical forward stepwise approach (Florax et al. 2003; for a specification of the test, see Florax and de Graaff 2004; Anselin 2006).

The current literature is not clear on which is the best way to represent the spatial relation between neighbours. A spatial weight matrix is, according to Anselin (1988, p.16): "formally expressing the way in which the structure of spatial dependence is incorporated in a model". In this paper three different ways are considered to model the spatial weight matrix. In the first and simplest model, a distance-based contiguity weight matrix is used. Neighbours are identified as neighbours if they are within a predetermined distance. In the second weight matrix model, the distance-based matrix is corrected for its transaction year in a two-directional way. It is plausible to assume that houses sold in different years are differently related in the spatio-time dimension. Two more recently sold houses have a larger spatial impact on each other than two houses whose transaction dates are further apart. In fact, we assume that time has a decaying effect on the spatial impact. Panel data would allow us to model time in a more explicit way, but unfortunately the data used has a cross-sectional character. The individual weights of the weight matrix are calculated in the following way:

$$w_{ij} = d_{ij} * e^{-\alpha \, * \, |\Delta year_{ij}|}. \tag{1}$$

The time-scaling factor is a decreasing exponential function of the absolute value of the time difference between two transactions. Thus the spatial weight is a contiguity-based distance d_{ij}, which is multiplied with this time scaling factor. In this paper different time-scaling corrections are presented to check whether they influence the spatial pattern. An important constraint for the distance used in the spatial weight matrix is that each observation has at least one neighbour, and using a time correction factor restricts the distance used. Setting α equal to 0 gives the first-mentioned weight matrix. The third way to model the weight matrix is the one where time influences the spatial weights in a sequential way, and this is discussed in the Appendix.

To test the presence of spatial autocorrelation, the Moran's I coefficients are calculated for each spatial weight matrix. For the complete results, we refer to the Appendix. In our discussion of the results, we focus on the first ($\alpha = 0$) and the second ($\alpha > 0$) weight matrix where the cut-off of the contiguity distance is 1000 metres.

Different decay specifications are compared by varying α in the time correction factor. The meaning of α equals 0 is that every neighbour within 1000 metres is influenced by the prices of its neighbour so that the time-scaling is absent. With α equal to 4, only transactions that take place in the same year within 1000 metres influence each other (the weight of a neighbour transaction a year ago is only 1.8 per cent). An α of 0.75 means houses which are sold three years ago have a 10 per cent weight.

The results of the Moran's I test as presented in Table 2 indicate the presence of spatial autocorrelation but, as stated by Anselin (2006), the test should not be interpreted as a test-statistic for spatial error correlation because the test has power for any alternative to spatial autocorrelation. To distinguish between spatial error dependence and spatial lag dependence Lagrange multiplier (LM) test statistics for spatial error and spatial lag are needed. Spatial error dependence is the spatial dependence in the error term, and spatial lag dependence is spatial dependence: neighbours influence each other in a reciprocal way in which spatial spillovers play a role. Both the LM error and the LM lag test statistics are significant for both specified OLS models. Unfortunately, the LM error test statistic is biased in the presence of spatial lag dependence, as the LM lag test is biased in the presence of spatial error correlation (Anselin 2006). Finally, the robust LM error test and the robust LM lag test are both significant for both models and all weight matrices. The size of the test results decreases when it is corrected for the possibility of the presence of the other type of spatial autocorrelation. The results of the one-directional time correction factor are similar to the time reciprocal corrections, as is shown in the Appendix.

Table 2 Spatial tests of "monument ensemble model" [a,b]

	α=0	α=0.75	α=4
Morans'I	25.0021	72.8963	37.6432
	(0.0000)	(0.0000)	(0.0000)
LM error	275.0089	4,591.8350	1,346.1419
	(0.0000)	(0.0000)	(0.0000)
LM lag	89.2608	474.8632	408.0882
	(0.0000)	(0.0000)	(0.0000)
LM robust error	243.0273	4,182.8471	999.2669
	(0.0000)	(0.0000)	(0.0000)
LM robust lag	57.2793	65.8753	61.2132
	(0.0000)	(0.0000)	(0.0000)

Notes: [a] Values shown are the test results with their p-value between parentheses.

[b] A 1000-metre-based contiguity matrix is used.

Although the various test results indicate that both forms of spatial dependence are present, it seems that there is more spatial error correlation than spatial lag dependence. As indicated by Anselin (2006), not correcting for spatial-lag dependence will lead to an omitted variable bias where not correcting for spatial error correlation leads to inefficient results. To correct for both, we estimate an appropriate version of the so-called Kelejian-Prucha model (Kelejian and Prucha 1998, 1999). Using the spatial autoregressive model with spatial autoregressive disturbances (as of now SARAR(1,1)):

$$\begin{aligned} &y = \lambda Wy + X\beta + u, |\lambda| < 1, \\ &u = \rho Wu + \varepsilon, \qquad |\rho| < 1, \\ &\varepsilon \sim N(0, \sigma^2), \end{aligned} \tag{2}$$

where y is a vector of deflated logarithmic prices for each sold house in our data set, and λ and ρ are, respectively, the spatial lag parameter and the spatial error parameter. The matrix X represents every observed characteristic where β is the estimated coefficient.

The spatial parameters of the final model are presented in Table 3. It summarizes the outcomes for λ and ρ for the second OLS model with various weight matrices. This SARAR (1,1) model has a significant lambda which indicates the presence of spatial-lag dependence and a positive ρ. The estimated results of ρ are relatively large. In the SARAR (1,1) with a decay parameter of α = 0.75, ρ equals 0.67. The magnitude of ρ may relate to an idiosyncratic spatial characteristic in the study area which was omitted because of data limitations. In the past, the deep foundations in Zaanstad were not made of concrete but of timber. To prevent deterioration of deep timber foundations, the groundwater should cover the timber. More recently, the groundwater situation has deteriorated, with, as a consequence, the rot of timber and the subsidence of the foundations of some houses. The level of the groundwater is geo-spatially related, and in that way it could influence the outcome of ρ. We find low values for the spatial-lag parameter λ (0.10 to 0.16).

In Table 4 the results of the SARAR (1,1) is presented with a spatial weight matrix which has a spatio-temporal relation where the decay is modest, with α equal to 0.75. Sensitivity tests for other values of α and other specifications are given in the Appendix. The results of Table 4 are directly comparable with those of the OLS estimates in Table 1.

Most coefficients have a similar magnitude as in the OLS estimation. An important feature of the results of this modelling procedure is that, contrary to their OLS outcomes, the estimates are efficient in a statistical sense, and the spatial multiplier gives us the opportunity to measure the full impact of each explanatory characteristic. In the first model, where the monument dummy variable measures the direct effect, and the monument density within a 50-metre radius measures the indirect effect, both coefficients are significant.

Won Kim et al. (2003) proved that when the weight matrix is row-standardized the multiplier equals $1/(1-\lambda)$. A spatial-lag parameter of 0.0971 as is the case in the non time scaled case means that the spatial multiplier is 1.11, which means that the estimated beta coefficients gain the multiplier as a spatial premium. When time weighting is incorporated in the spatial weight matrix, the multiplier increases to 1.19 (the $\alpha = 0.75$ case) and 1.14 (when $\alpha = 4$).

The direct monument status has a 21.6 ($e^{0.1957}$) per cent premium if the spatial multiplier is not applied to correct for the presence of spatial-lag dependence. Sold houses with a monument status gain this premium over non-monument houses. When correcting for the spatial dependence, this impact increases to 26.9 per cent, which means that, for an average house in the municipality of Zaanstad, the monetary premium is €41,100 for each monument. The indirect effect is a 0.23 per cent for each additional monument within a 50-metre radius when the spatial dependence is excluded. Spatially correcting, this indirect effect increases to 0.28 per cent, which means that, for the average house, each monument within a 50-metre radius contributes €430 to its value. Although this seems modest, one should take in account that monuments are often spatially-clustered.

As in the OLS, the second model adds a protected historic landscape dummy to check whether there are historic decor effects. The consequence of adding this variable is that the individual indirect effects of monuments, as measured by monument density within a 50-metre radius, diminish and become insignificant. This indicates that the original positive effect of this indirect effect was due to the positive effect of this protected historic area. The un-lagged direct effect decreases to 20 per cent, and the spatially-lagged direct effect decreases to 23.8 per cent, which is still a premium for the monument status of €38,100. The un-lagged effect for sold houses within a historic protected area gains a 22.2 per cent premium over houses sold outside this area, which means, for the average house, a premium of €35,500. This premium increases when the spatial multiplier corrects for the spatial-lag dependence, implying that houses within the historic district gain an eventual 26.4 per cent premium, the monetary equivalent of which is €42,200 for the average house. This means that monuments which are within a protected historic area gain a premium of more than 50 per cent compared with houses which are not monuments and are not within this historic area, which in monetary terms is €80,300.

In Appendix 2, the effect of various specified weight matrices on the results is analysed. The spatial test for the one-directional weight matrix indicates that the magnitude of the test is slightly smaller. Estimation results for spatial multipliers and monuments are very similar to those with the two directional weight matrix in Table 4.

Table 3 Spatial parameters of the "monument ensemble model" [a]

	α=0	α=0.75	α=4
λ	0.0971	0.1579	0.1207
p-value	(0.0000)	(0.0000)	(0.0000)
ρ	0.2902	0.6710	0.4102

Note: [a] A 1000-metre-based contiguity matrix is used.

Table 4 SARAR(1,1) with a 1000-metre-based contiguity matrix, α = 0.75

Variables	Direct and indirect monument effect			Monument ensemble effect		
Transaction-related characteristics						
Leasehold	-0.0581	***	(0.0052)	-0.0574	***	(0.0052)
Newly-built house	0.0224	*	(0.0169)	0.0237	*	(0.0169)
Sell condition (seller)	0.0189		(0.0185)	0.0202		(0.0185)
Sell condition (auctioned)	-0.1937	***	(0.0259)	-0.2097	***	(0.0260)
Structural characteristics						
Ln(Floor area)	0.1865	***	(0.0175)	0.1864	***	(0.0175)
Ln(Capacity)	0.4797	***	(0.0178)	0.4783	***	(0.0178)
Ln(Rooms)	0.0216	***	(0.0065)	0.0217	***	(0.0065)
Construction period unknown	-0.0993	***	(0.0240)	-0.1062	***	(0.0239)
Built before 1906	-0.1702	***	(0.0112)	-0.1726	***	(0.0112)
Built in the period 1906-1930	-0.1833	***	(0.0099)	-0.1843	***	(0.0098)
Built in the period 1931-1944	-0.1180	***	(0.0100)	-0.1194	***	(0.0100)
Built in the period 1945-1959	-0.0916	***	(0.0122)	-0.0929	***	(0.0121)
Built in the period 1960-1970	-0.1068	***	(0.0098)	-0.1080	***	(0.0097)
Built in the period 1971-1980	-0.0743	***	(0.0096)	-0.0733	***	(0.0096)
Built in the period 1981-1990	-0.0322	***	(0.0097)	-0.0333	***	(0.0097)
Built in the period 1991-2000	-0.0099		(0.0095)	-0.0108		(0.0094)
Spatial characteristics						
Busy street	-0.0044		(0.0059)	-0.0041		(0.0059)
Proportion of water area	0.1689	***	(0.0231)	0.1725	***	(0.0230)
Population density	-0.0104	***	(0.0008)	-0.0102	***	(0.0008)
Percentage ethnical	-0.0016	***	(0.0001)	-0.0016	***	(0.0001)
Distance to centre in km	0.0051	***	(0.0022)	0.0046	**	(0.0022)
Monument amenities						
Monument density/ha at a 50-metre radius.	0.0023	***	(0.0004)	-0.0010	*	(0.0006)
Monument dummy	0.1957	***	(0.0244)	0.1824	***	(0.0244)
Protected historic landscape			(0.0000)	0.2005	***	(0.0253)
Constant	6.5225	***	(0.1589)	6.6080	***	(0.1589)
λ	0.1644	***	(0.0130)	0.1579	***	(0.0130)
ρ	0.6670			0.6710		
Moran's I	-0.4603			-0.4042		
p-value	0.6453			0.6861		
Observations	19981			19981		

Notes: Standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.10.
Only part of the estimated coefficients is reported, full estimation results are available from the authors upon request.

6. Conclusion

In this paper the value of monument status as a public amenity is measured. One of the hypotheses is that monuments gain a premium over non-monuments. A related hypothesis is that monuments generate positive spillover effects, i.e. positive externalities, to real estate located in their vicinity. To test these hypotheses we first conducted an ordinary hedonic regression. The indirect monument effect is a rather local specific effect, within 50 metres –meaning that there is insignificant impact on the scenery and the historic decor if monuments are standing further away. This externality of single monuments on their neighbours is no longer found when we correct for the presence of the historic protected area. This may be interpreted as the importance of clustering of cultural historic built heritage, i.e. the historic ambience.

Monuments are not valued the same over time. In the Netherlands we saw this phenomenon just after the Second World War, when many where older buildings were demolished in favour of newly-built buildings, whereas today those older buildings are valued highly for their cultural significance. An result of the OLS regression is that the effect of monument density, tends to increase in the course of time on house prices. This means that, over time, people value the monuments in their neighbourhood more highly.

Our basic hedonic price model was apparently biased and not efficient due to the presence of spatial dependence. The spatial test results indicated that we should estimate a SARAR (1,1) specification to solve the spatial dependence. The resulting estimates are robust. In this spatial model, the spatial lag is estimated and is used to calculate the spatial multiplier. The spatial multiplier is influenced by the formulation of the weight matrix. In this paper we used a time-scaling factor to incorporate the impact of the year of transaction on the strength of the neighbour relation. Our research shows that the estimation results for the monument effects are rather insensitive for the specification adopted for one-directional versus two directional time-scaling. The results of the spatial econometric analysis are similar to those of the OLS estimates.

Monuments gain a premium over non-monuments of 23.8 per cent, and houses sold within a protected historic landscape a 26.4 per cent premium. This indicates that there exists a strong historic ensemble effect and that monuments are valued when they are clustered within an ensemble with historic ambience.

This paper used monument status as a proxy for listed heritage. An important limitation is that cultural heritage is not measured completely by using listed heritage. It would be interesting to approximate cultural heritage in a more comprehensive way in terms of the relative age of buildings, and also to measure subcategories of cultural heritage in order to investigate their marginal impact on real market behaviour. Clearly, also the spatial impact of neighbourhood quality deserves to be analysed in a more integrated way, for instance, by using more sophisticated geo-science methods. But our results are promising: it appears that the use of extensive micro transaction data in a spatial-econometric setting provides a firm proof of the impact of listed heritage on real estate values. In particular we have demonstrated a substantial positive externality of monuments on the values of other buildings in the form of an ensemble effect.

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Appendix 1 Variables and descriptive statistics

Table A.1 Variable names and definitions

Variable name	Definition	Unit
Dependent variable		
Transaction prince	Transaction price.	Euros
Transaction-related characteristics		
Leasehold	Dummy variable: equals 1 if the land is leased.	0,1
Newly-built house	Dummy variable: equals 1 if the house is a newly built house.	0,1
Sell condition (2x)	Dummy variables: equal 1 if the cost of purchasing the house are paid by the seller, or if the house is auctioned. Reference: cost paid by the buyer.	0,1
Structural characteristics		
Floor area	Size of living area of the house.	m^2
Capacity	Volume of the house.	m^3
Rooms	Number of rooms.	
Gas heater (2x)	Dummy variables: equal 1 if the house has a gas heater, or if the house has no heater. Reference: houses with central heating.	0,1
Insulation (3x)	Dummy variables: equal 1 if the house has one type of insulation, or two types of insulation, or three or more types of insulation. Reference: houses which have no insulation.	0,1
Maintenance inside (2x)	Dummy variables: equal 1 if the inside of a house is maintained good, or bad. Reference: houses where the inside is maintained normal.	0,1
Maintenance outside (2x)	Dummy variables: equal 1 if the outside of a house is maintained good, or bad. Reference: houses where the outside is maintained normal.	0,1
Garden (2x)	Dummy variables: equal 1 if the house has a no garden, or a well cared-for garden. Reference: houses which have a normal garden.	0,1
Parking (3x)	Dummy variables: equal 1 if the house has no parking opportunities, or has a carport and/garage, or has a garage for multiple cars. Reference: houses with a parking place available.	0,1
House type (13x)	Dummy variables: equal 1 if the house is a Terraced house, or a Canal side house, Mansion, Farm, Bungalow, Villa, Country house, Ground-floor flat, Upstairs flat, Maisonette, Gallery flat, Porch flat, Ground-floor and upstairs flat. Reference: family houses.	0,1
Year of construction (9x)	Dummy variables: equal 1 if the house is built before 1906, or in the period 1906-1930, 1931-1944, 1945-1959, 1960-1970, 1971-1980, 1981-1990, construction period unknown. Reference: houses that are built after 1990.	0,1
Spatial characteristics		
Village (7x)	Dummy variables for different villages equal 1 if the village is Assendelft, or Koog aan de Zaan, Krommenie, Westknollendam, Westzaan, Wormerveer, Zaandijk. Reference:houses located in Zaandam.	
Busy street	Dummy variable: equals 1 if the house is on a busy street.	0,1
Proportion of water area	The proportion of water area in the total surface of a district as used by Statistics Netherlands.	
Population density	Number of inhabitants per km^2.	
Percentage non-Western immigrants	Percentage of inhabitants of non-Western origin in the vicinity where the house is located.	
Monument amenities		
Monument density	Monument density/ha within a 50-metre radius.	
Monument house	Dummy variable: equals 1 if the house is a monument.	0,1
Protected historic landscape	Dummy variable: equals 1 is the sold house is within a protected historic landscape.	0,1

Table A.2 Descriptive statistics: mean values and std. dev. Zaanstad (n=19891)

	Mean	Std. dev.
Dependent variable		
Transaction price 2000 (€)	160,015	67,545
Transaction-related characteristics		
Leasehold	0.114	0.318
Newly-built house	0.008	0.087
Sell condition (buyer)	0.992	0.087
Sell condition (seller)	0.005	0.073
Sell condition (auctioned)	0.002	0.046
Structural characteristics		
Floor area (m^2)	107.3	32.5
Capacity (m^3)	311.6	100.8
Rooms	4.193	1.092
Gas heater (not present)	0.027	0.162
Gas heater (gas or coal)	0.126	0.332
Gas heater (central heating)	0.847	0.360
Insulation (not present)	0.182	0.386
Insulation (1 type)	0.334	0.472
Insulation (2 types)	0.171	0.377
Insulation (3 or more types type)	0.312	0.463
Maintenance good	0.004	0.062
Maintenance normal	0.842	0.365
Maintenance bad	0.154	0.361
Maintenance outside good	0.004	0.060
Maintenance outside normal	0.855	0.352
Maintenance outside bad	0.141	0.349
No garden	0.015	0.122
Normal cared-for garden	0.886	0.317
Well cared-for garden	0.098	0.298
No parking	0.814	0.389
Parking	0.031	0.173
Garage or carport	0.145	0.352
Multiple parking	0.011	0.102
Terraced house	0.103	0.304
Family house	0.602	0.490
Canal-side house	0.000	0.010
Mansion	0.077	0.267
Farm	0.001	0.033
Bungalow	0.012	0.109
Villa	0.009	0.092
Country house	0.001	0.034
Ground-floor flat	0.012	0.110
Upstairs flat	0.013	0.115
Maisonette	0.023	0.151
Porch flat	0.048	0.214
Gallery flat	0.098	0.297
Ground-floor and upstairs flat	0.000	0.017
Construction period unknown	0.003	0.053
Built before 1906	0.040	0.195
Built in the period 1906-1930	0.203	0.402
Built in the period 1931-1944	0.150	0.358
Built in the period 1945-1959	0.024	0.153
Built in the period 1960-1970	0.218	0.413
Built in the period 1971-1980	0.141	0.348
Built in the period 1981-1990	0.114	0.317
Built in the period 1991-2000	0.082	0.275
Built in the period 2001-	0.025	0.158
Spatial characteristics		
Busy street	0.046	0.210
Proportion of water area	0.112	0.070
Population density (inhabitants (in thousands)/km2)	5.297	2.319
Percentage ethnic	14.23	12.50
Distance to centre (km)	3.440	2.340
Monument amenities		
Monument density/ha at a 50-metre radius.	0.343	2.792
Monument dummy	0.003	0.051
Protected historic landscape	0.005	0.067

Appendix 2 Spatial weight matrix

Weight matrices can be specified in various ways. In order to determine the effect of different types of specification we conducted a sensitivity analysis. In the paper we discussed the outcomes of the SARAR (1,1) in the case where the weight matrix had a reciprocal character (see eq. 1). This equation implies temporal symmetry: house prices may be affected by both past and future prices. Another case is that only past transactions are considered. This would imply:

$$w_{ij}(\Delta year_{ij}) = \begin{cases} d_{ij} * e^{-\alpha * \Delta year_{ij}} & if \ \Delta year_{ij} \geq 0 \\ 0 & otherwise \end{cases}. \tag{3}$$

Table A.3 presents the test statistics for the model where the direct and indirect effects are estimated by the use of a monument dummy and the monument density within a 50-metre radius. The results indicate that the size of the test results decrease only a little indicating that our outcomes are robust.

Table A.3 Spatial tests in direct and indirect monument model at 1000 metres contiguity [a,b]

one directional	α=0	α=0.75	α=4
Moran's I	24.6707	72.7242	37.5887
	(0.0000)	(0.0000)	(0.0000)
LM error	267.5339	4,571.0841	1,342.3650
	(0.0000)	(0.0000)	(0.0000)
LM lag	98.7137	493.0960	423.6034
	(0.0000)	(0.0000)	(0.0000)
LM robust error	234.1068	4,150.8667	986.3603
	(0.0000)	(0.0000)	(0.0000)
LM robust lag	65.2866	72.8786	67.5986
	(0.0000)	(0.0000)	(0.0000)

Notes: [a] Values shown are the test results with their p-value between parentheses.

[b] A 1000-metre-based contiguity matrix is used.

To check whether the spatial effects change due to the predetermined distance we have increased the cut-off distance to 1750 metres. Tables A.4 and A.6 report the results where the cut-off distance is increased to 1750 metres. A cut-off distance of 1750 metres gives the opportunity to specify the weight matrix in a one-directional way following eq. (3), because with that distance every sold house has a neighbour house sold within the same year of transaction. From Table A.4 it is seen that an increased cut-off distance decreases the test results for spatial dependence. The α = 0 test results for the one-directional formulation are somewhat unusual, but this is because the number of neighbours is small resulting in small sample estimates. Comparing the time-reciprocal case with the one-directional case of α = 4 shows that the outcomes of the one-directional formulation are close to those of the time reciprocal case.

Table A.4 Spatial tests at 1750 metres contiguity [a,b]

	Direct and indirect monument model			Monument ensemble model		
	α=0	α=0.75	α=4	α=0	α=0.75	α=4
time reciprocal						
Moran's I	32.7047	50.7160	24.4760	32.7319	50.5115	24.3675
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
LM error	338.5184	2,109.2685	558.2158	338.4598	2,091.6505	553.1785
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
LM lag	131.6363	244.1083	173.2744	125.6003	235.1914	167.0889
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
LM robust error	294.2644	1,906.7248	414.9529	295.4021	1,895.0901	413.9501
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
LM robust lag	87.3823	41.5645	30.0115	82.5426	38.6310	27.8605
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
one directional						
Moran's I	39.7058	38.3126	23.7277	39.1818	38.0997	23.6150
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
LM error	798.8754	1,292.4774	525.1346	776.5363	1,277.7972	520.0586
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
LM lag	3.6629	211.7930	172.7130	3.7166	203.6347	166.6313
	(0.0556)	(0.0000)	(0.0000)	(0.0539)	(0.0000)	(0.0000)
LM robust error	799.4423	1,116.0758	384.4235	777.0980	1,106.9853	383.2587
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
LM robust lag	4.2299	35.3915	32.0019	4.2782	32.8229	29.8313
	(0.0397)	(0.0000)	(0.0000)	(0.0386)	(0.0000)	(0.0000)

Notes: [a] Values shown are the test results with their p-value between parentheses.
[b] A 1750-metre-based contiguity matrix is used.

In Table A.5 the spatial parameters are shown for the indirect case. The parameters appear to be larger compared to the estimated model in the text.

Table A.5 Spatial parameters at 1000 metres contiguity [a,b]

	Direct and indirect monument model		
	α=0	α=0.75	α=4
time reciprocal			
λ	0.1563	0.1644	0.1258
	(0.0000)	(0.0000)	(0.0000)
ρ	0.2527	0.6670	0.4061

Notes: [a] Values shown are the test results with their p-value between parentheses.
[b] A 1000-metre-based contiguity matrix is used.

The spatial parameters in Table A.6 compare the time-reciprocal case with the one-directional case. As mentioned, $\alpha = 0$ is not estimated correctly because of data limitations. Comparing the remainder of the parameters we may conclude that the one directional case has roughly the same size.

Table A.6 Spatial parameters at 1750 metres contiguity [a,b]

	Direct and indirect monument model			Monument ensemble model		
	α=0	α=0.75	α=4	α=0	α=0.75	α=4
time reciprocal						
λ	0.3213	0.2317	0.1756	0.2902	0.2265	0.1708
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
ρ	1.1731	0.5541	0.3576	0.9535	0.5565	0.3595
one directional						
λ	-0.0005	0.2080	0.1815	-0.0005	0.2023	0.1766
	(0.2398)	(0.0000)	(0.0000)	(0.2358)	(0.0000)	(0.0000)
ρ	0.9438	0.5017	0.3569	0.9604	0.5034	0.3586

Notes: [a] Values shown are the test results with their p-value between parentheses.

[b] A 1750 meter based contiguity matrix is used.

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